FFA@CEBAF collaboration

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Recent regular attendees

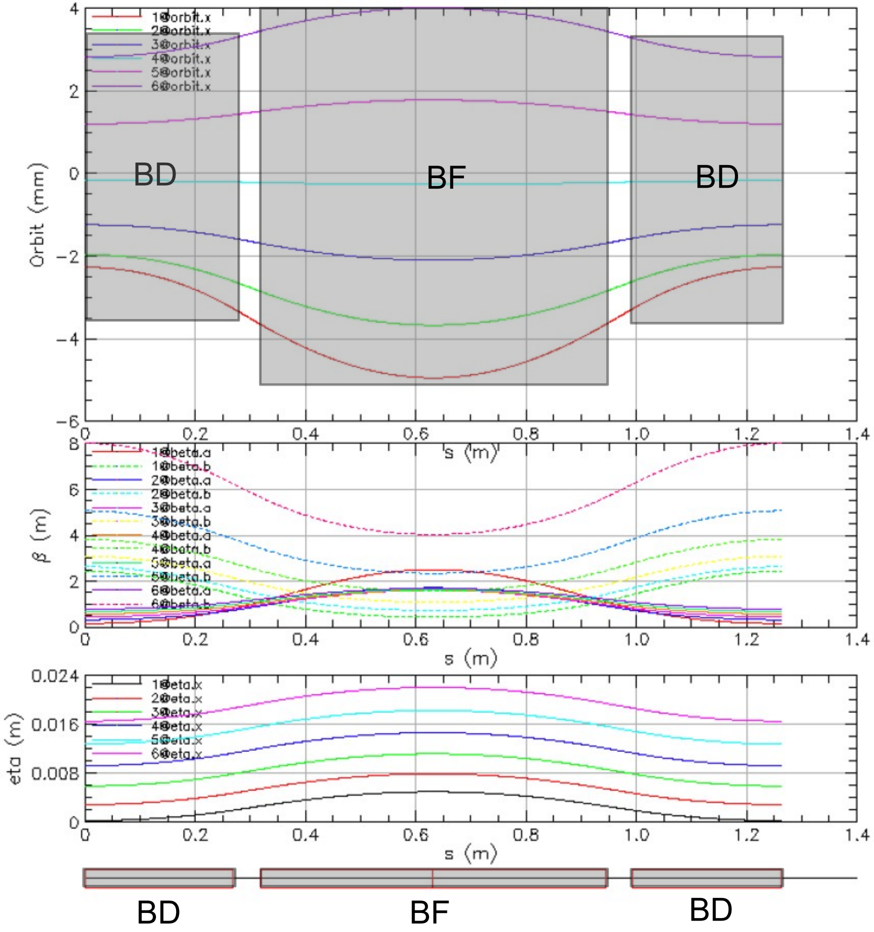
Outline

- Concept
- Energy range
- Current status
- Difficulties remaining
- Conclusion

Fixed Field alternating gradient Accelerators

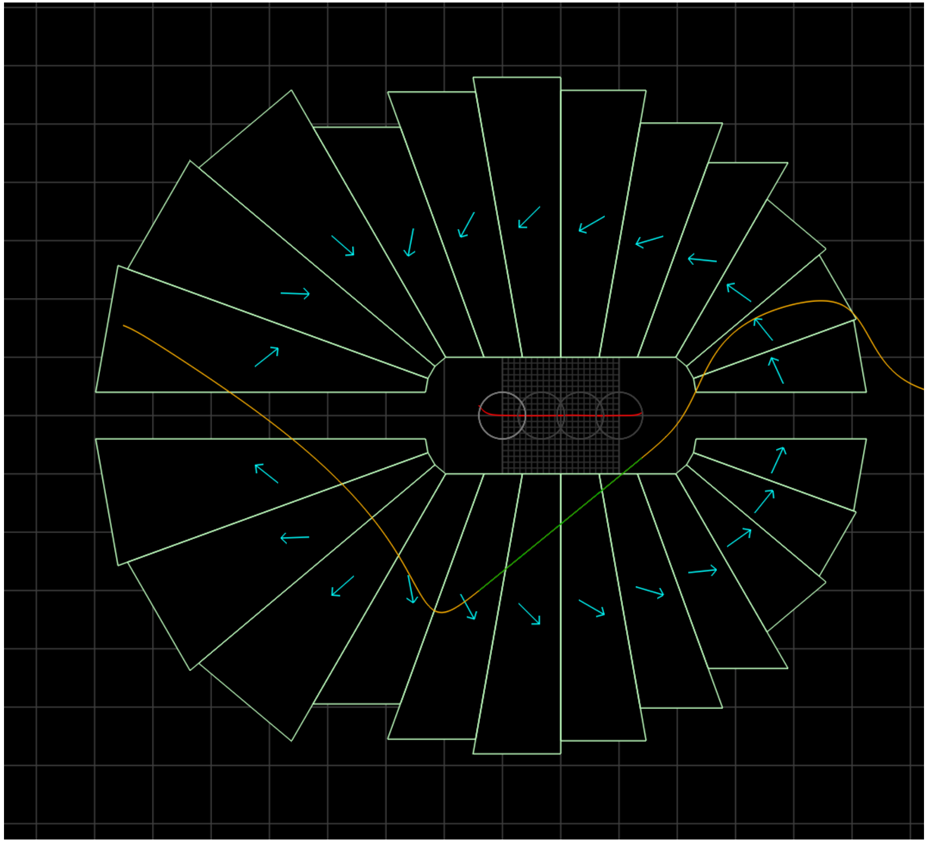
- Remove one or two of the higher pass electromagnetic arcs and replace them with combined function magnets which are designed to allow a range of energies in the same magnet. Typically ~2:1 range.
- CBETA at Cornell was a successful demonstration at 150 MeV
- FFA at CEBAF would be a major step up in energy for FFAs
- Permanent magnet development lead at BNL, Stephen Brooks, has an LDRD for design and development of magnets suitable for use here
- Ryan Bodenstein, CASA, has an LDRD for end to end simulation of FFA at CEBAF. LDRD funds are being applied for learning of BMAD, the chosen code, by Ryan and students. Definition of the beam line **not** included.

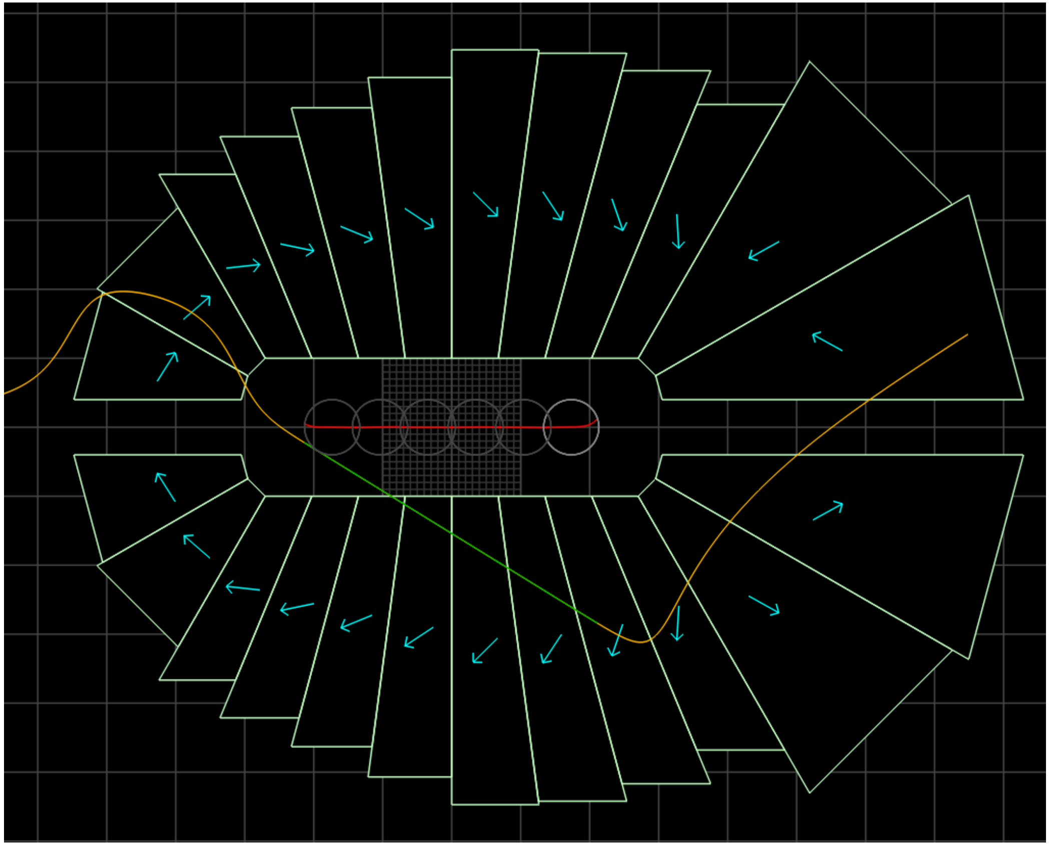
Unit cell



Large momentum acceptance FFA cell, configured with combined function magnets capable of transporting multiple energy beams through the same string of permanent magnets. BD horizontally diverging aka vertically focusing. BF horizontally focusing. Both also have dipole component. Very low dispersion (eta).

Permanent magnets (S. Brooks)





Left BD 105.8 cm^2 of permanent magnet material. Right BF 100.4 cm^2 Squares span 1 cm.

Injector and linac modification

- The biggest optics problem in CEBAF is the ratio of injection energy to sixth pass through North Linac: 90:1. Beam envelope is large on fifth and sixth passes and particle loss has been observed via NDX detectors.
- The working group proposes to solve this by building a two-pass recirculating linac with three new cryomodules in a new vault adjacent to the existing tunnel in lieu of the 55 m injector chicane. Final energy 650 MeV. Ratio at start of NL on way to Halls A/B/C 34:1. SL 19:1
- All linac girders will be replaced as electromagnetic triplet focusing is needed to allow beta function control. BPMs and correctors will be placed between the three quads on each new girder.

Energy Range

Linac pass	Linac	Energy (MeV)	SR (MeV)	Line
0	injector	649	0.00	injector
1	North-1	1749	0.01	EM1E
2	South-1	2849	0.10	EM1W
3	North-2	3949	0.36	EM2E
4	South-2	5049	0.97	EM2W
5	North-3	6148	2.14	EM3E
6	South-3	7245	4.14	EM3W
7	North-4	8341	5.06	FFA1-1E
8	South-4	9436	5.76	FFA1-1W
9	North-5	10530	7.27	FFA1-2E
10	South-5	11623	11.00	FFA1-2W
11	North-6	12712	19.16	FFA1-3E
12	South-6	13793	34.63	FFA1-3W
13	North-7	14858	61.06	FFA1-4E
14	South-7	15897	101.93	FFA1-4W
15	North-8	16895	54.73	FFA2-1E
16	South-8	17941	63.24	FFA2-1W
17	North-9	18977	75.64	FFA2-2E
18	South-9	20002	93.36	FFA2-2W
19	North-10	21008	118.38	FFA2-3E
20	South-10	21990		Hall B
		21920	70.00	Halls A, C

Linac energy assumed 1100 MeV.

Three electromagnetic passes retained. Two FFAs used to limit energy range to 2.3:1 in each so peak is less than 1.6T in the good field region.

Final energy 22 GeV limited by feasible Hall line arc dipoles. TN-21-051.

HT Stephen Brooks

Energy steps

linac energy=	925	1000	1100
extraction energy			
first	2400	2590	2850
second	4250	4590	5050
third	6090	6590	7250
fourth	7930	8580	9440
fifth	9770	10570	11620
sixth	11600	12540	13790
seventh	13370	14450	15900
eighth	15090	16310	17940
ninth	16820	18180	20000
tenth	18490	19990	21990

Stephen Brooks uses 925-1100 MeV as the linac energy range in his permanent magnet design efforts to keep peak field down.

First three passes are electromagnetic so 2.0-7.25 GeV continuously available if FFAs are not used. 2 GeV minimum chosen to limit span of Hall dipoles to 11:1.

The collaboration does not yet have a concept for extracting the energies shown in red.

Current status

- Collaboration has been working on lattice design for CEBAF proper for over a year.
- Ryan Bodenstein, Alex Coxe (grad student) and Katheryne Price (operator) are learning Bmad, chosen accelerator modeling software, with LDRD funding. The rest of us are charging to usual accounts.
- Tasks for the remainder of the machine have been assigned. I have been asked to work on the Hall lines. Given the energy range required, these have to be electromagnetic.

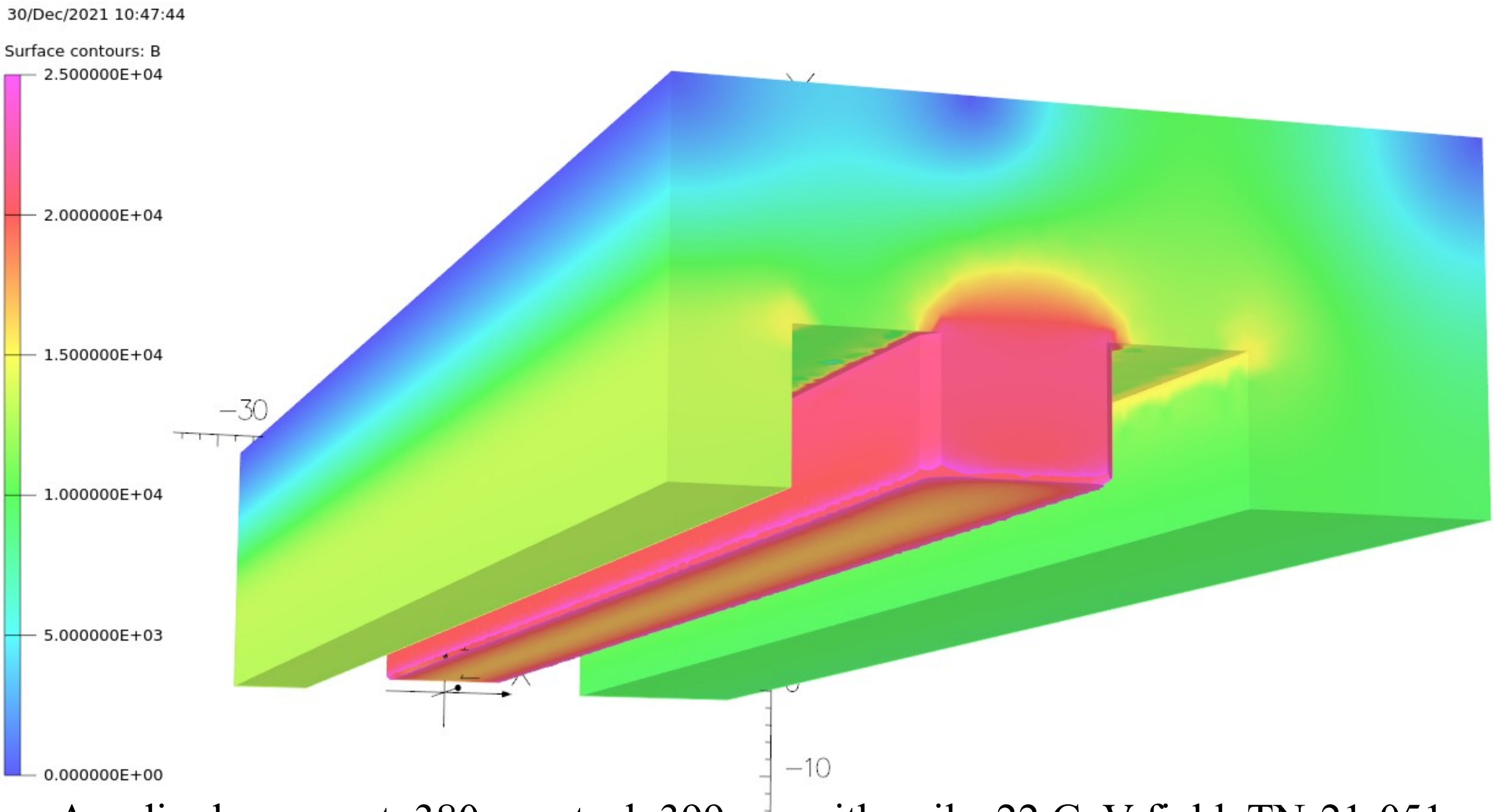
Challanges Remaining (1)

- Lambertson plate with B beam passage is saturated at 11 GeV to A/C
- Lambertson will have to be lengthened from 230 cm to 380 cm and plate thickened from 17.8 mm to 20 mm.   Dipole which closes horizontal dispersion will also have to be lengthened, to 200 cm. Total dipole length increase, aka drift space which has to be recovered elsewhere, 250 cm.
- If the A/B/C beam separation could be increased in the transport recombiner more than 2.2 mm assumed above the new Lambertson might be shorter. Even the additional ±1.1 mm about the B beam location assumed may be difficult to deliver. Hall A beam may be left at present height and B/C lowered.
- The only way to obtain 250 cm is to completely rebuild the BSY. Quad spacing in the non-dispersive region has to be reduced. Beam dumplets and safety equipment have to be moved downstream. I just started this effort. Hall A energy measurement harp pair spacing reduced to match Hall C's. Etc.

Challenges Remaining (2)

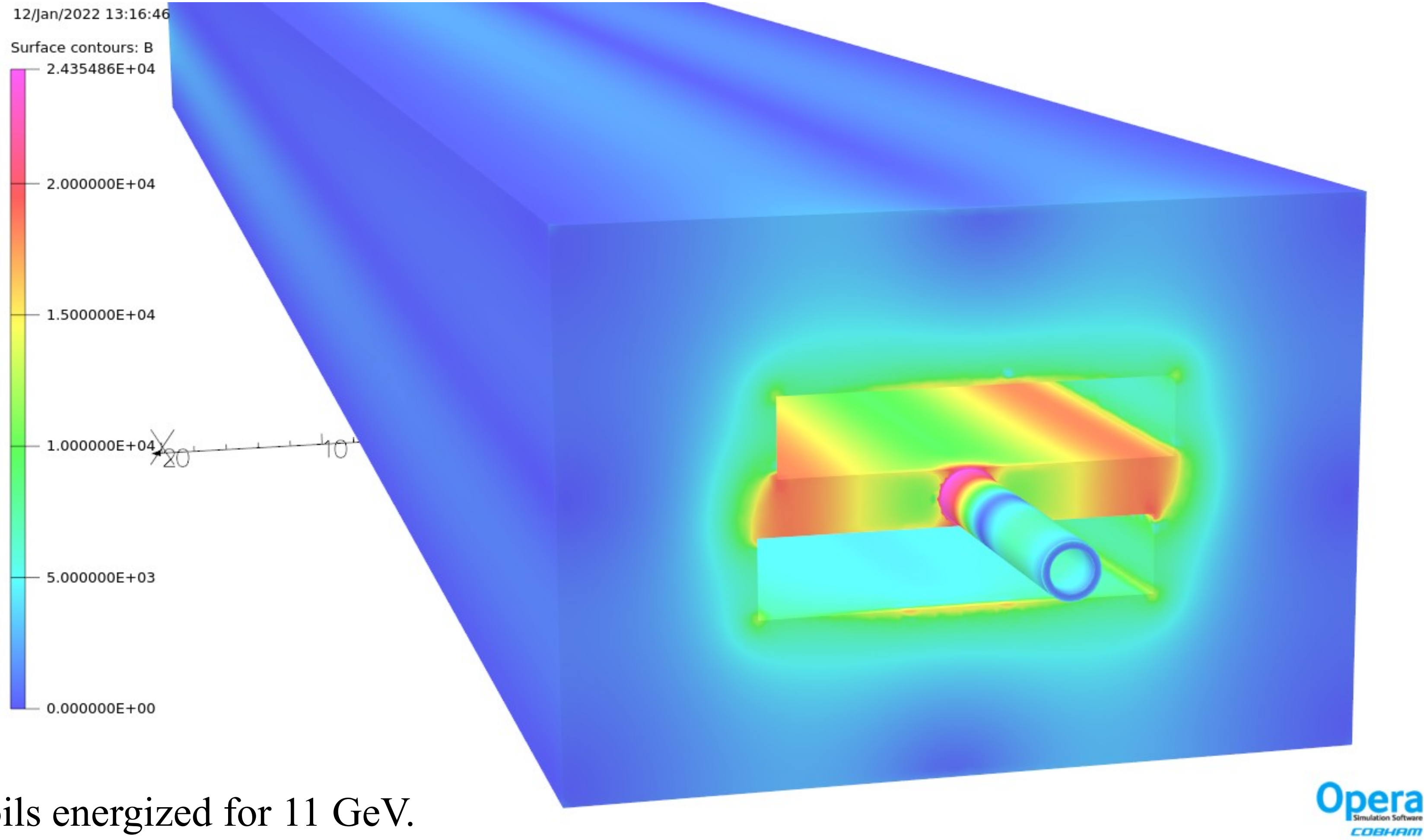
- Extraction of beams on intermediate FFA passes to the halls.
- Detailed design of vertical spreaders and recombiners in the main machine, much less the transport recombiner with its need to separate A/B/C beams vertically.
- In addition to the vertical spreaders/recombiners, within each FFA there are horizontal spreaders needed to compensate for the pathlength difference due to the different energies in the arcs. These must also have some adjustability to keep bunches on crest in the linac.
- Stronger correctors have been designed for MOLLER; procurement underway. 20" versions of the 14" QR quads will be needed in many places in the hall lines.
- Arc 1 and 2 dipoles will likely have to be replaced due to the higher injection energy. Other arcs may have to be altered. All arc magnet stands may have to be altered/replaced given FFAs.

Hall Arc Dipole Concept



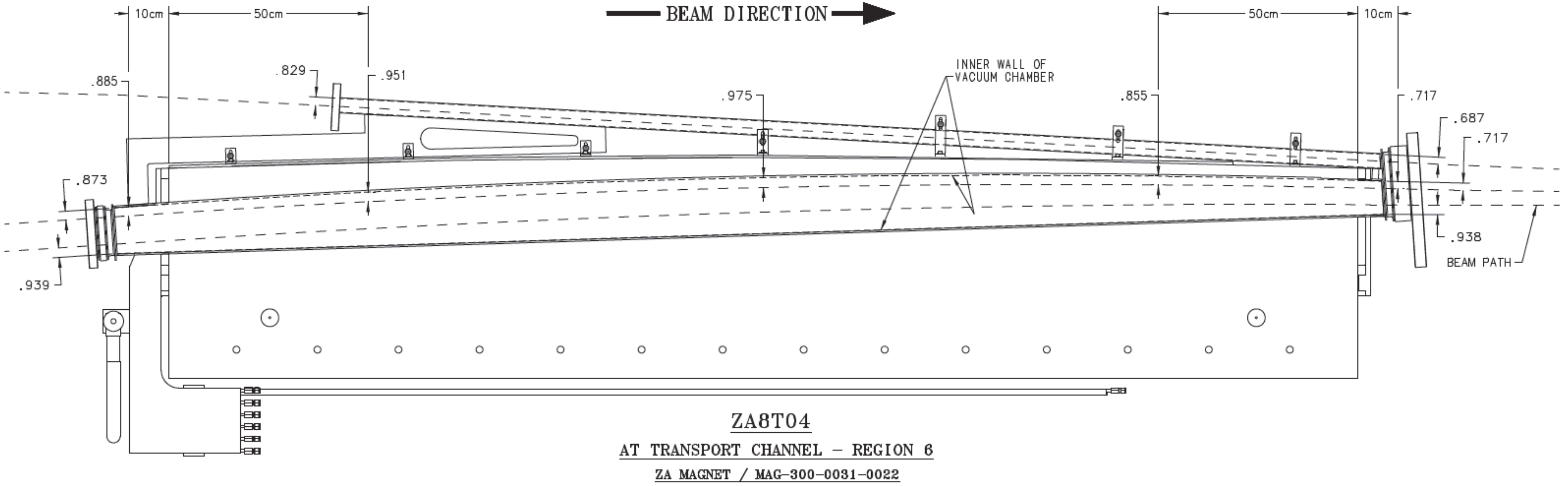
Arc dipole concept 380 cm steel, 399 cm with coils, 22 GeV field, TN-21-051.
120 cm remains for BPM, quad, corrector, bellows. Vacuum? Harp??

Lambertson now



Both coils energized for 11 GeV.

B beams through MZA8T04



Third, fourth and fifth pass from top to bottom. Dimensions inches. A and C beams about 0.4" above/below B beam to reach correct holes in Lambertson in remaining drift. Exact locations needed to determine if plate thickness can be increased beyond 20 mm.

Conclusions

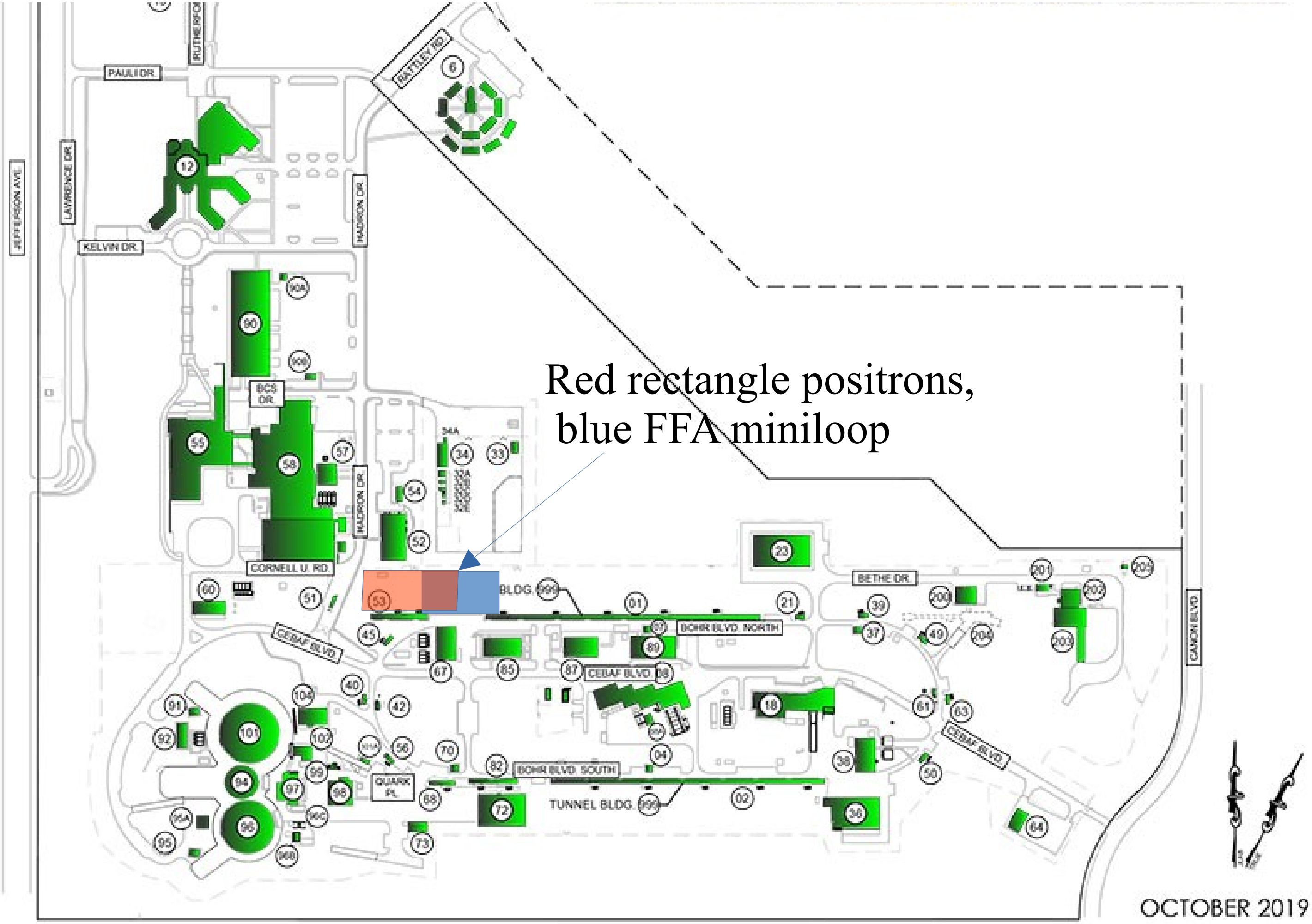
- We have a very long way to go before there is a self-consistent layout.
- We do not yet know if extraction is feasible at intermediate passes of the FFAs. There may be large energy gaps.
- This project would be a lot more difficult than the 12 GeV Upgrade and would require much more alteration of magnet systems.

Input Requested for White Paper and IPAC

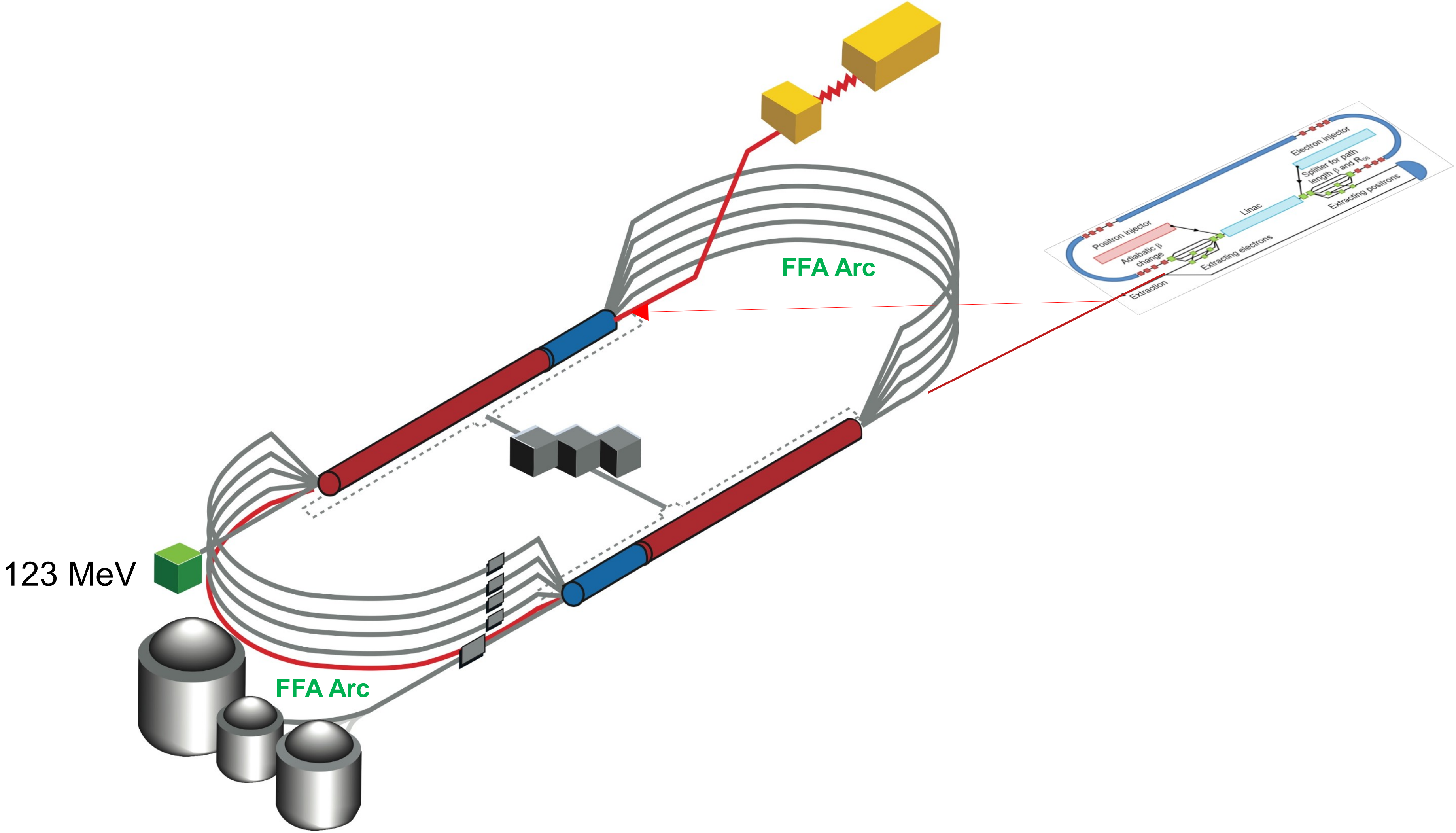
- What physics drives the higher energy?
- What physics drives the needed energy spacing?
- Which is more important, physics with positrons or higher energy? (Vault for intermediate injector may preclude positron source.)
- What questions do you have that I might answer now?
- What modifications do you want the collaboration to work on? Priority?
- Email me!

Backup slides

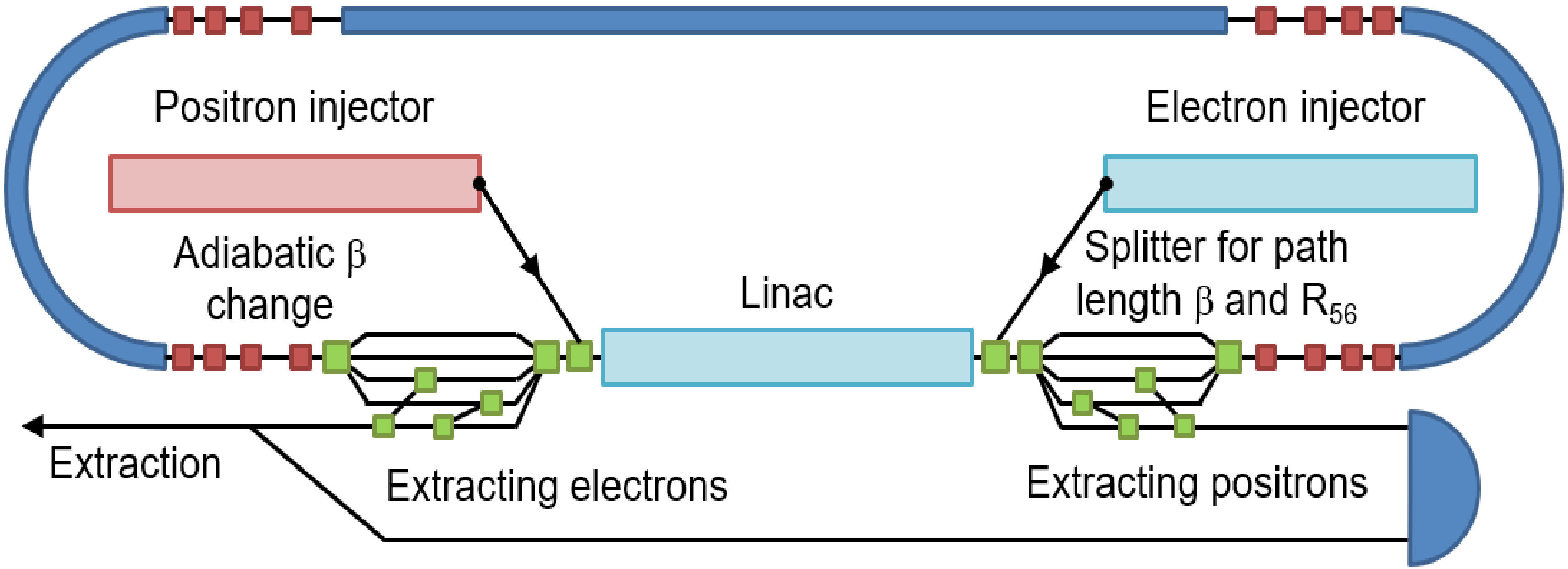
Red rectangle positrons,
blue FFA miniloop



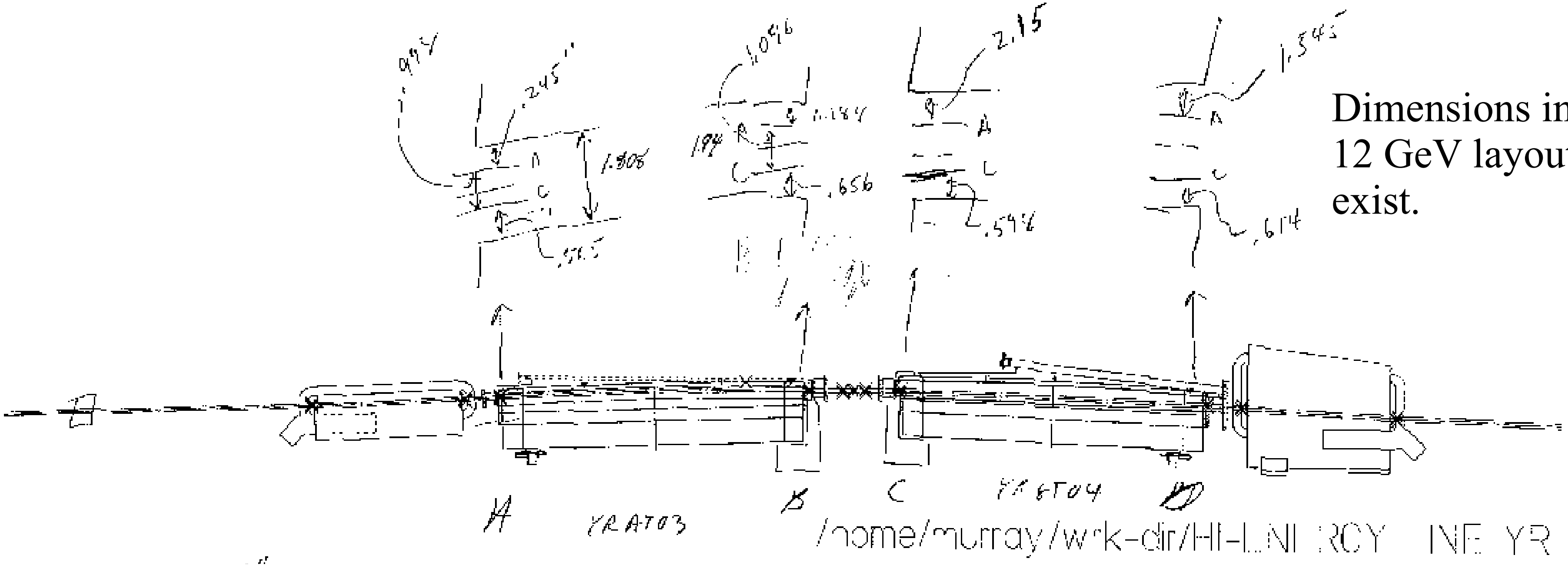
OCTOBER 2019


FFA Arc
123 MeV
FFA Arc
Electron injector
Splitter for path length β and R_{56}
Linac
Extracting positrons
Positron injector
Adiabatic β change
Extracting electrons
Extraction

1.2 GeV FFA booster injector



6 GeV AT layout



Dimensions inches.
12 GeV layout does not exist.

Other Benesch work that might be of use

- TN-20-044 An improved 104 mm ID quadrupole (use in extraction?)
- TN-18-037 FEM models and Fourier decomposition of three thick septa (YR, Lambertson, unbuilt combo) also JINST